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New Records of Acanthoceratid Ammonoids from the Upper Cenomanian of South Dakota

W. J. KENNEDY,¹ W. A. COBBAN,² AND N. H. LANDMAN³

ABSTRACT

The upper Cenomanian *Metoicoceras mosbyense* zone of the Belle Fourche area in Butte County, South Dakota, has yielded a number of ammonoid species, some of them new, that show both U.S. Western Interior and northwest European affinities, including *Calycoceras* (*Calycoceras*) *boreale* n. sp., *C. (C.)* sp., *C. (C.)* cf. *dromense* (Thomel, 1972), *Calycoceras* (*Gentoniceras*) sp., *Hamites cimarronensis* (Kauffman and Powell, 1977), *Neocardioceras transiens* n. sp., *Protacan-*

thoceras proteus vascoceratoides Wright and Kennedy, 1987, and *Yezoites* n. sp. These species are similar to those reported from the *M. mosbyense* zone in southwestern New Mexico and suggest a possible influx of forms from the south, migrating via the Gulf Coast region, well before the better-known interchange of Western Interior and more cosmopolitan taxa in the succeeding *Sciponoceras gracile* zone.

INTRODUCTION

The bulk of the ammonoid species known from the upper Cenomanian *Metoicoceras mosbyense* zone in the northern part of the Western Interior of the United States are en-

demic species (fig. 1). This is in marked contrast to the predominantly cosmopolitan assemblage known in the succeeding *Sciponoceras gracile* zone (for a description of this

¹ Curator of the Geological Collections, University Museum, Parks Road, Oxford, OX1 3PW, United Kingdom.

² Research Scientist Emeritus, U.S. Geological Survey, Box 25046, Mail Stop 919, Federal Center, Denver, CO 80225.

³ Curator and Chairman, Department of Invertebrates, American Museum of Natural History.

SUBSTAGE	ZONE
UPPER CENOMANIAN	<i>Nigericeras scotti</i> <i>Neocardioceras juddii</i> <i>Burroceras clydense</i> <i>Sciponoceras gracile</i> <i>Metoicoceras mosbyense</i> <i>Dunveganoceras problematicum</i> <i>Dunveganoceras pondi</i>

Fig. 1. Upper Cenomanian ammonite zonation in the central and northern parts of the U.S. Western Interior [modified from Cobban, 1988, table 2]

latter fauna, see Cobban and Scott, 1972). Several northwest European and more cosmopolitan species are known from the *M. mosbyense* zone in the southernmost parts of the Western Interior Seaway (southwestern New Mexico), where Cobban et al. (1989) recorded *Calycoceras* (*Proeulycoceras*) *guerangeri* (Spath, 1926a), *Eulycoceras pentagonum* (Jukes-Browne, 1896), *Euomphaloceras euomphalum* (Sharpe, 1855), *Hamites* cf. *H. simplex* (d'Orbigny, 1842), and *Vascoceras diartianum* (d'Orbigny, 1850). *Eulycoceras pentagonum* is also present in the *Sciponoceras gracile* zone in southeastern Colorado as well as in the *S. gracile* zone in the Black Hills area.

It is, therefore, of paleobiogeographic interest to record the presence of several ammonoid species, one of which also occurs in northwest Europe, from the *Metoicoceras mosbyense* zone in the northern part of the Western Interior Seaway. These ammonoids occur in the Greenhorn Formation of the Belle Fourche area, Butte County, South Dakota, considerably farther north than the New Mexican occurrences cited above, and include *Calycoceras* (*Calycoceras*) *boreale* n. sp., *C. (C.)* sp., *C. (C.)* cf. *dromense* (Thomel, 1972), *Calycoceras* (*Gentonoceras*) sp., *Hamites cimarronensis* (Kauffman and Powell, 1977), *Neocardioceras transiens* n. sp., *Protacanthoceras proteus vascoceratoides* Wright and Kennedy, 1987, and *Yezoites* n. sp. (The two heteromorphs, *H. cimarronensis* and *Ye-*

zoites n. sp. are not described in the systematic section of this paper, but will be treated elsewhere.)

Of these species, *Protacanthoceras proteus vascoceratoides* also occurs in northwest Europe (Wright and Kennedy, 1987). *Hamites cimarronensis* occurs elsewhere in the Western Interior Seaway including Oklahoma, Colorado, and Texas (Kauffman and Powell, 1977). The other species cited are related to forms previously reported from New Mexico and northwest Europe.

The exact age relationship between the ammonoids in South Dakota and those in New Mexico is difficult to resolve. It is possible that the ammonoids in South Dakota occur higher up in the *Metoicoceras mosbyense* zone than those in the south and, therefore, the two occurrences are not exactly equivalent in age. Nevertheless, we suggest that the ammonoids in South Dakota may have migrated from the south, via the Gulf of Mexico, rather than from the north, through Hudson Bay. This hypothesis is based on the presence of related species to the south, albeit not necessarily of exactly equivalent age, and the complete absence of any related species in this zone to the north, for example, in central Montana (Cobban, 1952).

GEOGRAPHIC AND STRATIGRAPHIC SETTING

The following localities are referred to in the text and indicated in figure 2:

AMNH locality 3155—Greenhorn Formation, west side of the Belle Fourche Reservoir in the S½ sec. 15, T9N, R3E, Butte County, South Dakota.

USGS Mesozoic locality D10511—Greenhorn Formation, east bank of the Belle Fourche Reservoir in the NW¼ sec. 30, T9N, R4E, Butte County, South Dakota.

USGS Mesozoic locality D10512—same as D10511, but a few meters higher in the section.

The stratigraphic sequence at AMNH locality 3155 is shown in figure 3. At this locality, the Greenhorn Formation consists of a succession of fine silty, calcareous shales, interbedded with layers of flat, ovoid, red-orange weathering concretions less than 30 cm in diameter. The *Metoicoceras mosbyense*

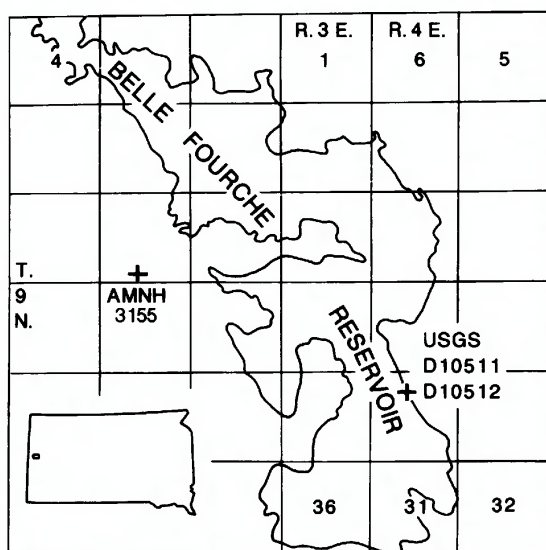


Fig. 2. Map of parts of T9N, R3 and 4E, Butte County, South Dakota, showing localities mentioned in the text. Each section is one square mile.

zone is exposed in the lower part of this section below the *Sciponoceras gracile* zone.

The ammonoids described in this paper come from an interval 4.9 m above the base of the measured section, in the *Metoicoceras mosbyense* zone. They occur in light-grey to yellowish-grey weathering limestone concretions, less than 15 cm in diameter; most of these concretions are, in fact, large fragments of ammonoid body chambers, such as those of *Calycoceras* (*Calycoceras*) *boreale* n. sp., with smaller, more complete ammonoids embedded inside (fig. 7A). Maeda (1991) called this mode of preservation "sheltered preservation" and described similar occurrences from the Upper Cretaceous Yezo Group of Japan.

CONVENTIONS

The following abbreviations are used to indicate repositories of specimens:

- AMNH American Museum of Natural History, New York
 BMNH British Museum (Natural History), London
 USNM U.S. National Museum of Natural History, Washington, D.C.

All dimensions of specimens are expressed

in millimeters, with D = diameter, W = whorl width, H = whorl height, and U = umbilical diameter measured at the umbilical wall. The angle of the body chamber (BC \angle) is expressed in degrees. Suture terminology is that of Wedekind (1916) as expounded by Kullmann and Wiedmann (1970). Photographs of specimens are natural size unless otherwise indicated. Arrows on photographs indicate the apical end of the body chamber, where preserved. The orientations in which specimens were photographed are shown in figure 4.

SYSTEMATIC PALEONTOLOGY

ORDER AMMONOIDEA ZITTEL, 1884

SUBORDER AMMONITINA HYATT, 1889

SUPERFAMILY ACANTHOCERATACEAE

DE GROSSOUVRE, 1894

FAMILY ACANTHOCERATIDAE

DE GROSSOUVRE, 1894

SUBFAMILY ACANTHOCERATINAE

DE GROSSOUVRE, 1894

GENUS AND SUBGENUS

CALYCO CERAS HYATT, 1900

TYPE SPECIES: *Ammonites navicularis* Mantell, 1822: 198, pl. 22, fig. 5, by designation under the Plenary Powers (ICZN Opinion no. 557).

Calycoceras (*Calycoceras*) *boreale*,
 new species
 Figures 5–9

DERIVATION OF NAME: Latin, *borealis*, northern.

DIAGNOSIS: A coarsely ribbed species of *Calycoceras* (*Calycoceras*); on the inner whorls, umbilical and inner ventrolateral tubercles are approximated on a short rib, with no flank tubercles; ventrolateral shoulders occupy most of the whorl height; the venter is broad, with outer ventrolateral and siphonal clavi.

TYPES: Holotype AMNH 44332 (fig. 5I, J) from AMNH locality 3155; paratypes AMNH 44317, 44318, 44329–44331, all from AMNH locality 3155, and USNM 441253 and 441255, both from USGS Mesozoic locality D10512.

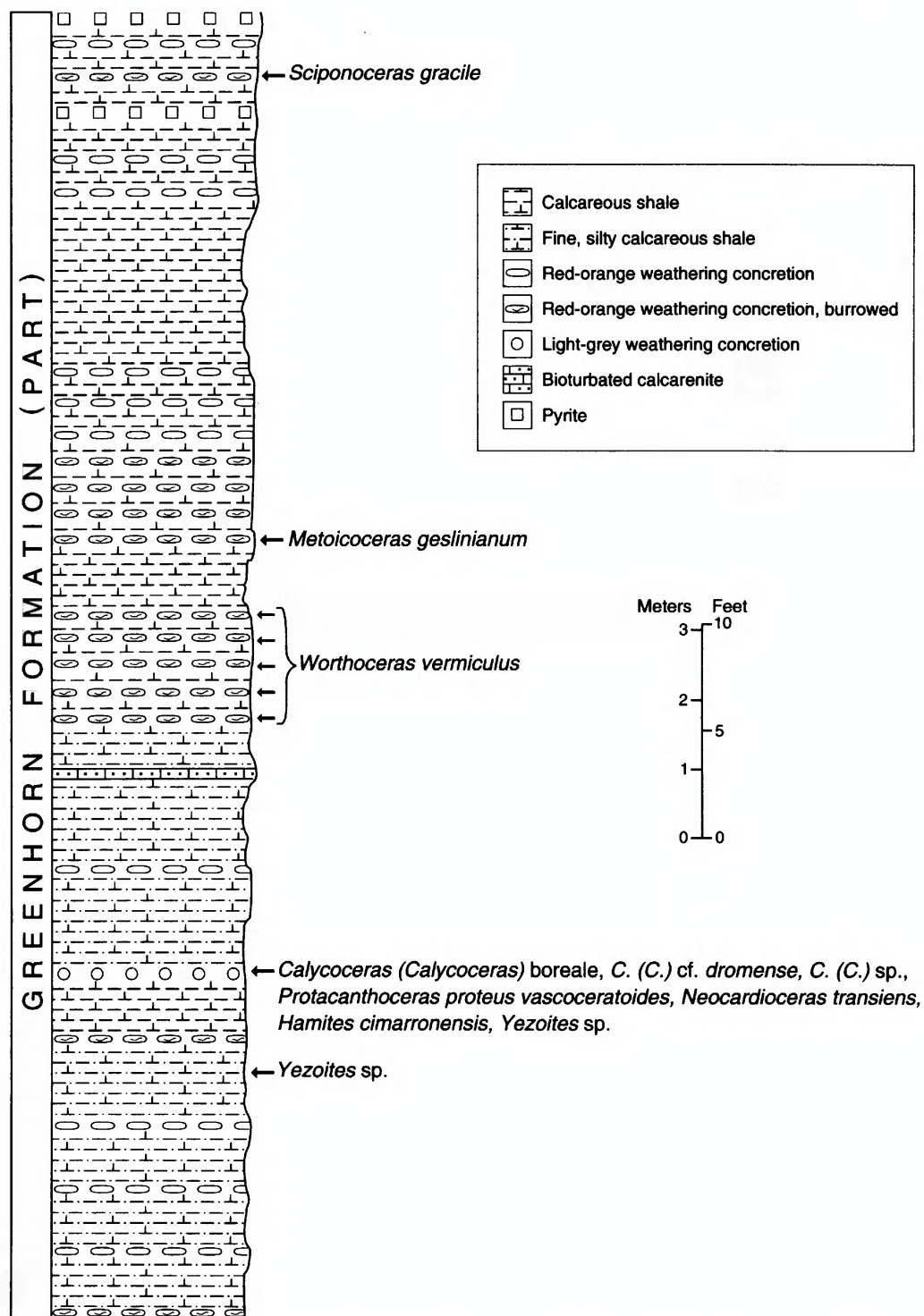


Fig. 3. The stratigraphic succession in the Greenhorn Formation at AMNH locality 3155 on the west side of the Belle Fourche Reservoir.

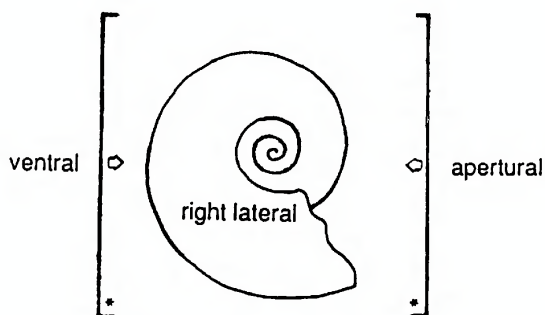


Fig. 4. Specimens are illustrated in lateral, ventral, and apertural views. Asterisks indicate the up position in each view.

DESCRIPTION: The dimensions of the holotype and three of the paratypes are listed in table 1. The holotype, AMNH 44332 (fig. 5I, J), is completely septate and shows depressed costal and intercostal sections (fig. 8). Ten or eleven massive primary ribs bear strong umbilical and inner ventrolateral tubercles and give rise to one or two secondary ribs; there are occasional intercalated ribs; altogether, there are 22 ribs per whorl. All of these ribs are straight and coarse and bear strong, blunt outer ventrolateral and somewhat weaker, siphonal clavi.

Paratype 44329 (fig. 5E–H) is also completely septate. Coiling is moderately involute with a deep umbilicus comprising approximately 30 percent of the diameter. The intercostal whorl section is very depressed and reniform; the ratio of whorl width to height in costal section is 1.83:1 (table 1). Ornament is very coarse with massive, bituberculate primary ribs that give rise to groups of two or three straight to slightly convex, rursiradiate secondary ribs with occasional intercalated ribs, all with well-developed, outer ventrolateral and siphonal clavi.

Paratype AMNH 44330 (fig. 5A–D) is completely septate and partially crushed. Coiling is moderately involute, with a deep umbilicus and high, broadly rounded umbilical wall. The whorl section is depressed and reniform with the greatest width just outside the umbilical shoulder in intercostal section and at the umbilical ribs in costal section. There are 10 or 11 massive primary ribs per whorl, each bearing a minute, umbilical tubercle and a larger, inner ventrolateral tubercle. These ribs

give rise to one or two coarse, strong secondary ribs. One or two short intercalated ribs appear between the primary ribs both high and low on the ventrolateral shoulder; they strengthen and match the secondary ribs on the venter. All ribs are straight and rectiradiate to slightly rursiradiate and bear weak, outer ventrolateral and siphonal clavi, the latter connected by a delicate siphonal ridge.

Paratype AMNH 44331 (fig. 5K, L) is also completely septate; the innermost whorls, visible within the umbilicus of the specimen, show massive bituberculate ribs, 11 or 12 per whorl, starting at a very small diameter. On the outer whorl, coarse, rectiradiate to feebly rursiradiate secondary ribs arise in groups of two or three from massive primary ribs; there are occasional intercalated ribs. Small, outer ventrolateral and siphonal clavi are present on all ribs, but the delicate siphonal ridge visible in other specimens, e.g., AMNH 44330, is absent.

Paratype USNM 441255 (fig. 6) is a large, completely septate fragment of the outer whorls, with a maximum whorl height of approximately 80 mm. Coiling appears to have been moderately evolute with a deep umbilicus having a high, rounded umbilical wall. The whorl section is very depressed, with an estimated costal whorl width-to-height ratio of 1.20:1. The costal whorl section is polygonal with the greatest width at the umbilical bullae; the venter is broad and flat. The intercostal section is depressed and reniform, with the maximum width just outside the umbilical shoulder. Coarse, low primary ribs occur on the umbilical wall and strengthen into strong umbilical bullae that give rise to coarse, rursiradiate, straight to weakly concave primary ribs. There is a change in rib profile at the inner ventrolateral position, but there is no tubercle; ribs strengthen across the ventrolateral shoulder and link to blunt, outer ventrolateral clavi. Weaker, but still coarse, blunt ribs extend across the venter. Shorter, intercalated ribs alternate regularly with the primary ribs and arise around mid-flank; they strengthen to match the primary ribs on the ventrolateral shoulder and venter.

The suture has fingerlike digitations; E/L is broad and L is narrow and asymmetrically bifid (fig. 9).

DISCUSSION: *Calycoceras* (*Calycoceras*) *bo-*

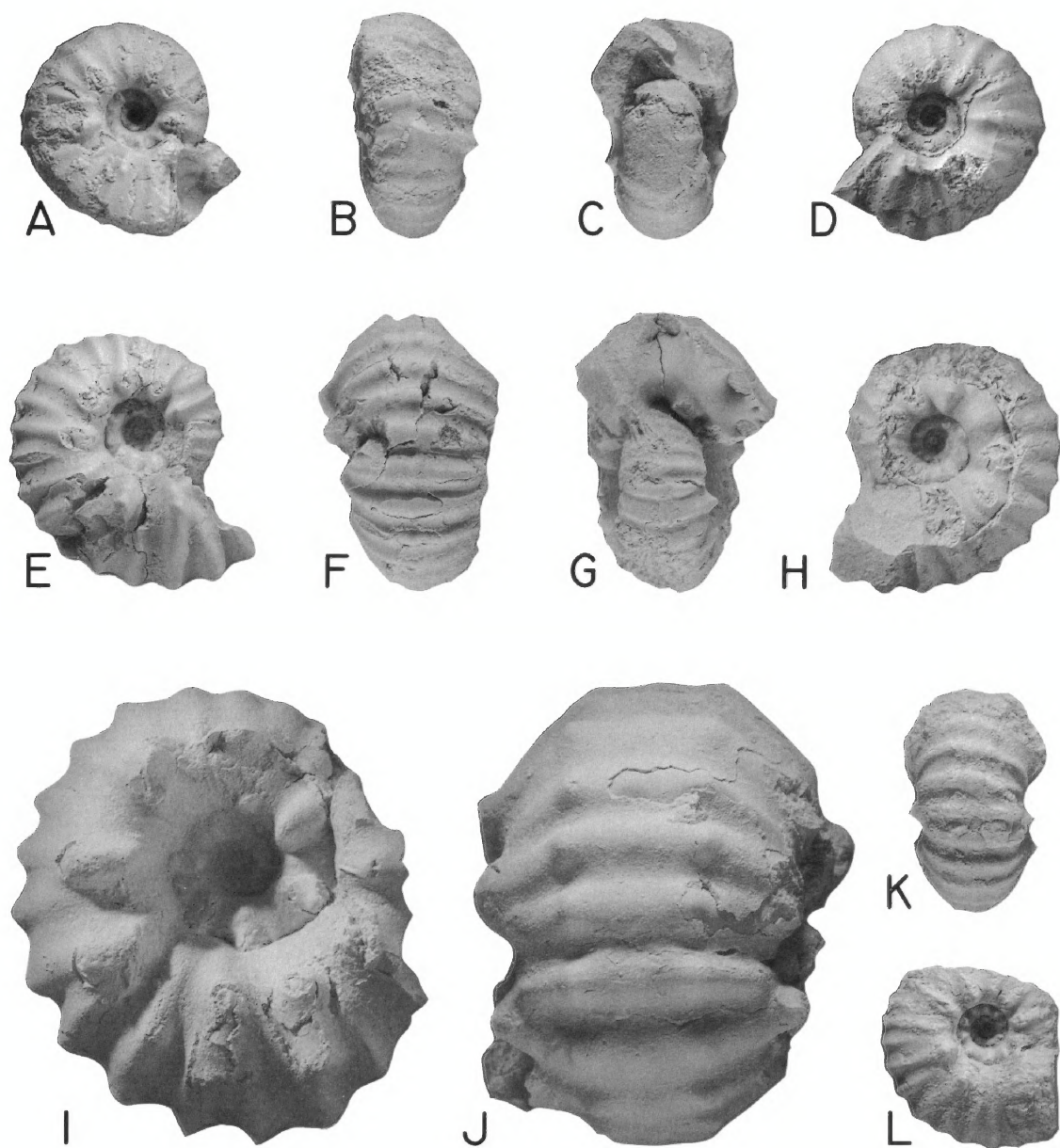


Fig. 5. *Calycceras (Calycceras) boreale* n. sp., AMNH locality 3155. A–D. Paratype AMNH 44330, $\times 2.0$. A, Right lateral; B, ventral; C, apertural; D, left lateral. E–H. Paratype AMNH 44329 (same specimen as in fig. 9). E, Right lateral; F, ventral; G, apertural; H, left lateral. I, J. Holotype AMNH 44332 (same specimen as in fig. 8). I, Right lateral; J, ventral. K, L. Paratype AMNH 44331. K, Ventral; L, right lateral.

reale n. sp. shows an even greater reduction in flank height and approximation of umbilical and inner ventrolateral tubercles than does the type species *C. (C.) naviculare* (Man-

tell, 1822) (see revision in Wright and Kennedy, 1990: 236, pl. 61, fig. 1; pl. 62, figs. 1–6; pl. 63, figs. 1–3; text-figs. 88E, I, 89D, 110C). In addition, *C. (C.) boreale* has coars-



Fig. 6. *Calycoceras (Calycoceras) boreale* n. sp., A, B. Paratype USNM 441255, USGS Mesozoic locality D10512, $\times 0.92$. A, Left lateral; B, ventral. Note that the adoral direction is toward the top in both views.

er ribs and siphonal clavi, the latter persisting beyond the diameter where they are already absent in *C. (C.) naviculare*. There are similarities to *C. (C.) inflatum* Cobban, Hook, and Kennedy, 1989 (p. 25, fig. 71A–F), but

C. (C.) inflatum has umbilical, lateral, inner and outer ventrolateral, and siphonal tubercles, as does *Calycoceras (Proeulcalycoceras)* sp. nov. of Cobban, Hook, and Kennedy, 1989 (p. 26, fig. 74H), both of which were originally

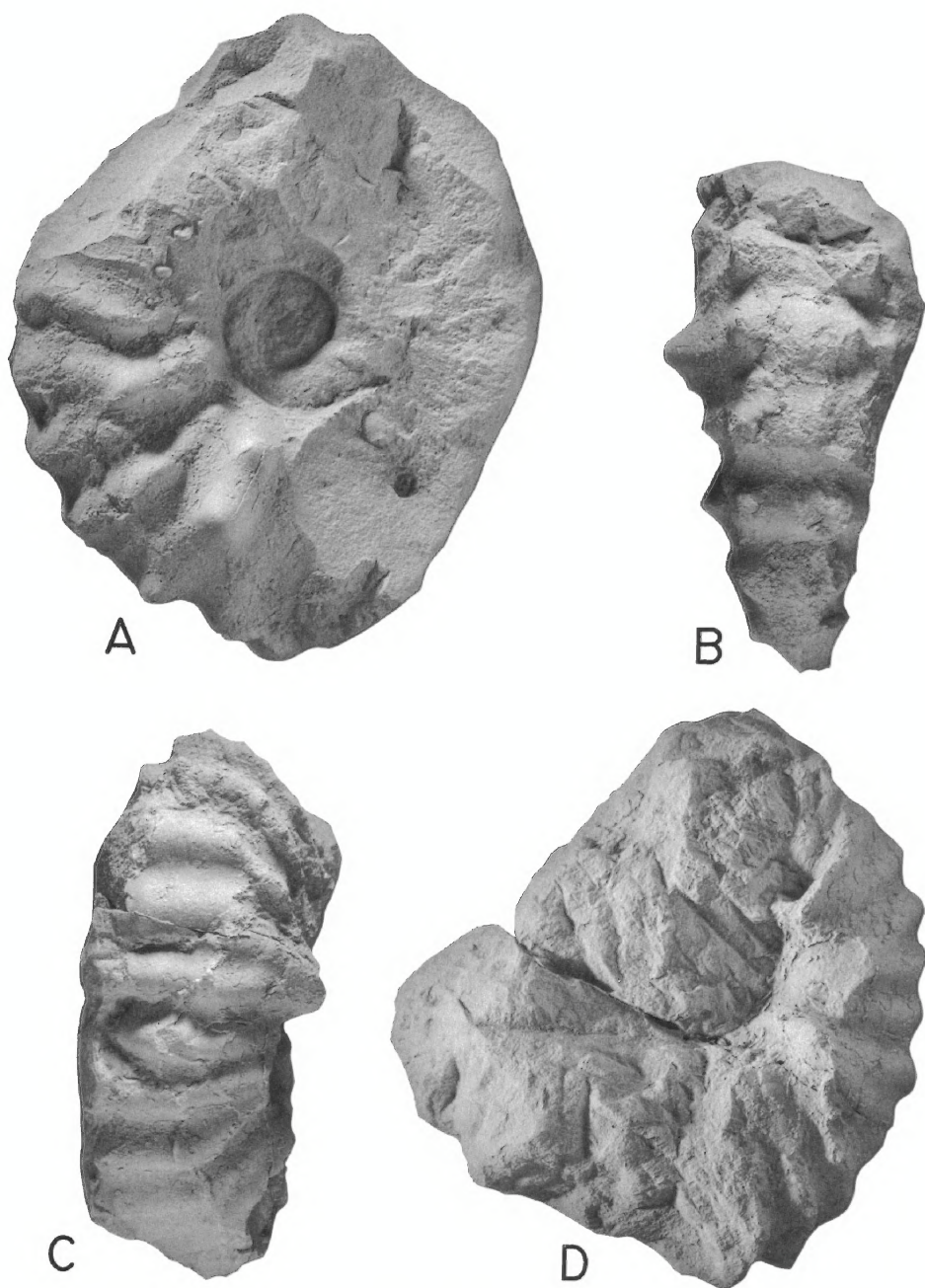


Fig. 7. *Calycoceras* (*Calycoceras*) *boreale* n. sp. A, B. Paratype AMNH 44317, AMNH locality 3155. A, Right lateral, note the presence of another ammonite, probably *Protacanthoceras proteus vascoceratoides*, embedded inside the body chamber; B, ventral. C, D. Paratype USNM 441253, USGS Mesozoic locality D10511. C, Ventral; D, left lateral.

described from the upper Cenomanian of New Mexico.

OCCURRENCE: *Metoicoceras mosbyense* zone of the Greenhorn Formation on the west

side of the Belle Fourche Reservoir in the S½ sec. 15, T9N, R3E and on the east bank of the Reservoir in the NW¼ sec. 30, T9N, R4E, Butte County, South Dakota.

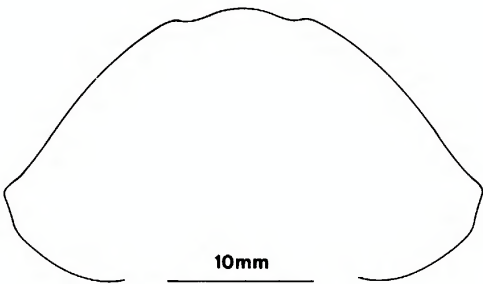


Fig. 8. Costal whorl section of *Calyccoceras* (*Calyccoceras*) *boreale* n. sp., holotype AMNH 44332, AMNH locality 3155 (same specimen as in fig. 5I, J).

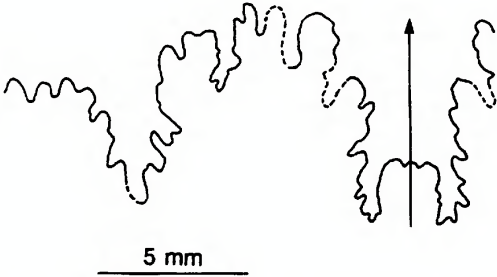


Fig. 9. *Calyccoceras* (*Calyccoceras*) *boreale* n. sp., paratype AMNH 44329, AMNH locality 3155 (same specimen as in fig. 5E–H). Composite partial suture based on the next-to-last, third-to-last, and fifth-to-last visible sutures at D = 31.6, 30.6, and 27.1 mm, respectively.

Calyccoceras (*Calyccoceras*) cf. *dromense*
(Thomel, 1972)
Figure 10F, G

Compare: *Pseudocalyccoceras* (*Pseudocalyccoceras*) *dromense* Thomel, 1972: 94, pl. 30, figs. 8, 9.

DESCRIPTION: USNM 441254 is a body chamber fragment with a maximum costal whorl height of 43.4 mm, with part of the nucleus preserved (fig. 10F, G). The inner whorls show coarse primary ribs with umbilical bullae and massive lateral tubercles. The body chamber fragment bears strong, narrow, widely spaced rursiradiate ribs, regularly alternating, long and short. Long ribs arise at the umbilical seam, and strengthen across the umbilical wall; each rib bears a very strong bituberculate bulla perched on the umbilical shoulder. Strong, narrow ribs are rursiradiate across the flanks and bear weak, bullate, inner ventrolateral tubercles and strong, outer ventrolateral clavi. These latter are linked across the venter by high, narrow ribs with pronounced siphonal clavi.

No sutures are visible on the specimen.

DISCUSSION: The presence of lateral tubercles immediately distinguishes this fragment from *C. (C.) boreale* n. sp. described above. It most closely resembles *C. (C.) dromense* (Thomel, 1972: 94, pl. 30, figs. 8, 9), originally described from the upper Cenomanian of southeast France; this species has a similar disposition of tubercles, but fewer intercalated ribs, hence, the qualified assignment of this fragment.

OCCURRENCE: *Metoicoceras mosbyense* zone of the Greenhorn Formation on the east bank of the Belle Fourche Reservoir in the NW¼ sec. 30, T9N, R4E, Butte County, South Dakota.

Calyccoceras (*Calyccoceras*) sp.
Figures 10A–C, 11–13

DESCRIPTION: AMNH 44333 is a completely septate fragment 26.4 mm in diameter (fig. 10A–C). Coiling is evolute, with the umbilicus comprising 23 percent of the diameter. The umbilicus is moderately deep, with a

TABLE 1
Dimensions of *Calyccoceras* (*Calyccoceras*) *boreale* n. sp. (in millimeters)^a

Specimen	Description	D	W ^b	H ^b	W:H ^b	U
Holotype AMNH 44332	Phragmocone	64.3 (100)	47.5 (73.9)	28.4 (44.2)	1.67:1	18.7 (29.1)
Paratype AMNH 44329	Phragmocone	38.6 (100)	30.0 (77.7)	16.4 (42.5)	1.83:1	11.4 (29.5)
Paratype AMNH 44330	Phragmocone	15.3 (100)	— ^c	— ^c	— ^c	4.5 (29.4)
Paratype AMNH 44331	Phragmocone	21.0 (100)	12.6 (60.0)	9.4 (44.8)	1.34:1	5.9 (28.1)

^a Figures in parentheses are dimensions as a percentage of diameter.
^b Measured in costal section if ribs are present.
^c — Specimen is not well enough preserved to be measured.

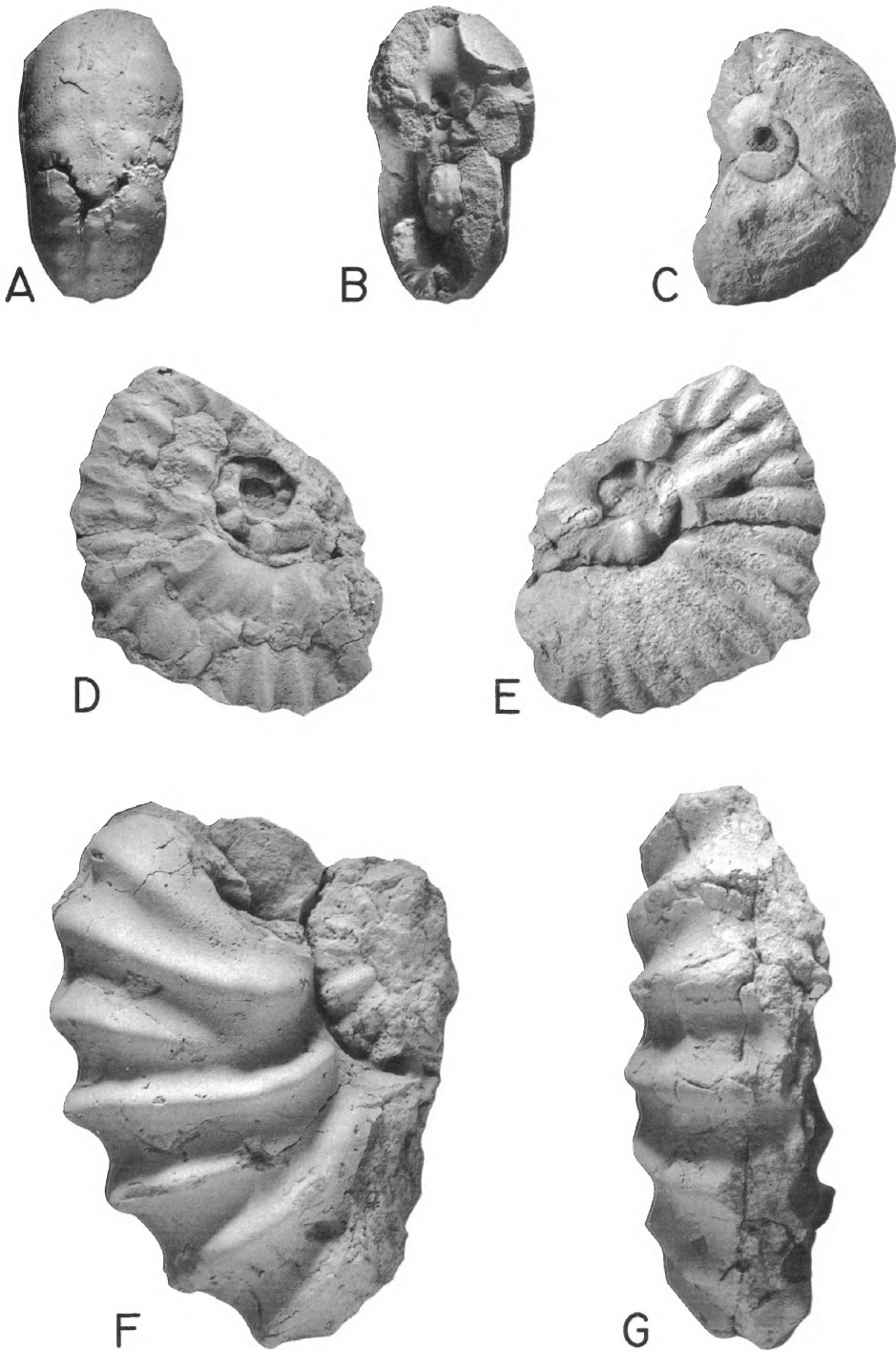


Fig. 10. A–C. *Calyoceras* (*Calyoceras*) sp., AMNH 44333, AMNH locality 3155, $\times 1.5$ (same specimen as in fig. 13). A, Ventral; B, apertural; C, left lateral. D, E. *Calyoceras* (*Gentoniceras*) sp., AMNH 44318, AMNH locality 3155. D, Right lateral; E, left lateral. F, G. *Calyoceras* (*Calyoceras*) cf. *dromense* (Thomel, 1972), USNM 441254, USGS Mesozoic locality D10511. F, Right lateral; G, ventral.

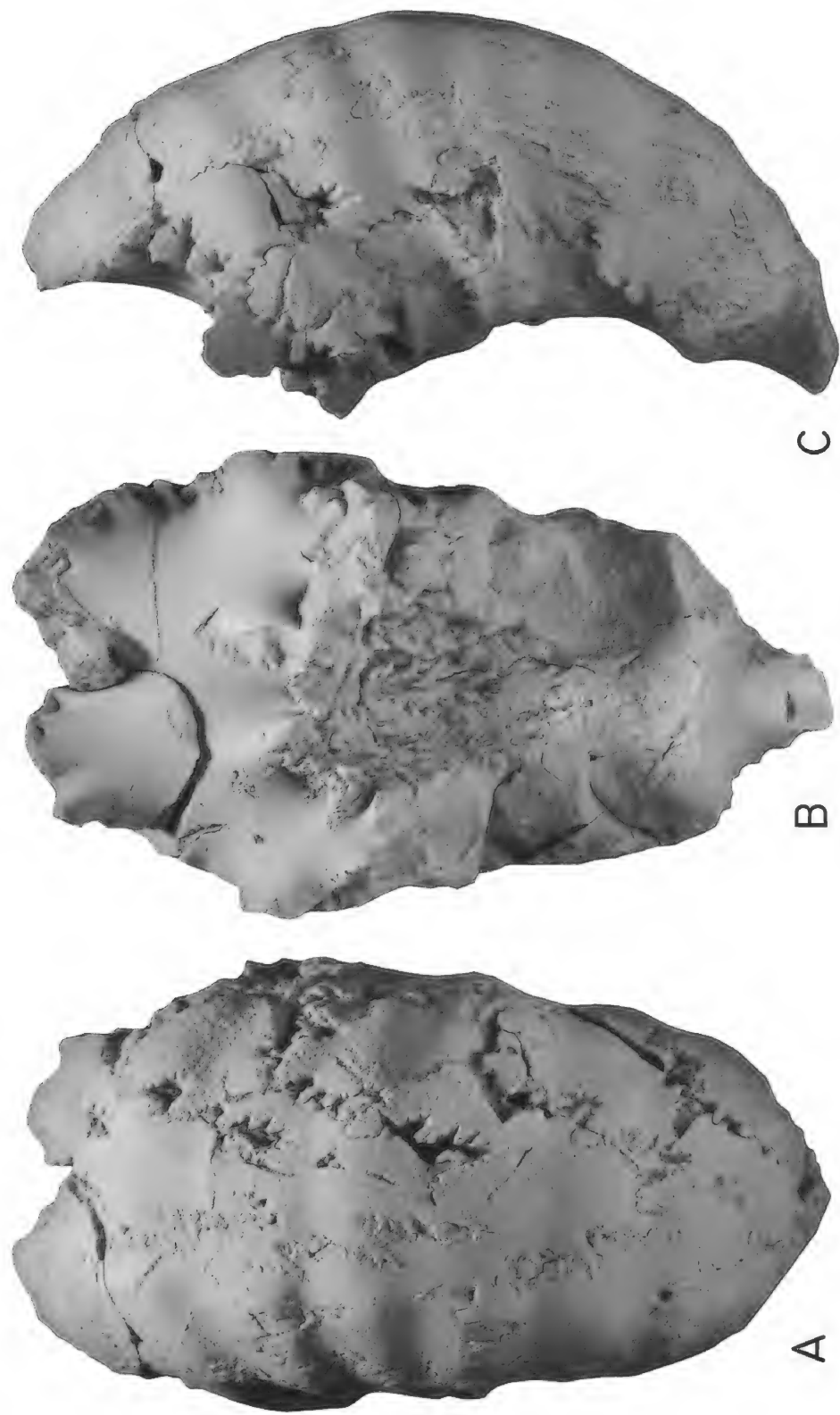


Fig. 11. *Calycoceras* (*Calycoceras*) sp., AMNH 44334, AMNH locality 3155 (same specimen as in fig. 12). A, Ventral; B, apertural; C, right lateral. Note that the adoral direction is toward the top in all three views.

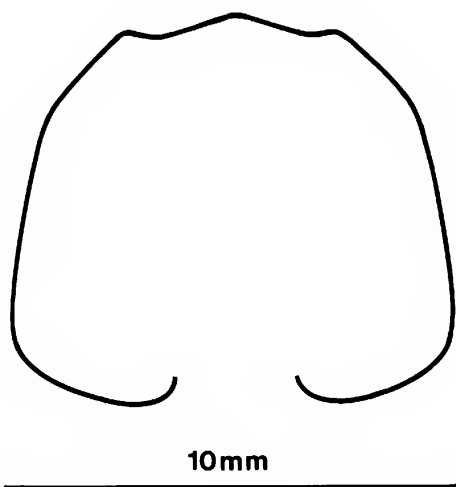


Fig. 12. Costal whorl section of *Calyoceras* (*Calyoceras*) sp., AMNH 44334, AMNH locality 3155 (same specimen as in fig. 11).

broadly rounded umbilical wall, and a narrowly rounded umbilical shoulder. The costal whorl section is depressed and trapezoidal, with broadly rounded flanks and ventrolateral shoulders, and a broad, flattened venter. The inner whorls at an estimated diameter of 8 mm show clearly differentiated umbilical bullae and ventrolateral and siphonal clavi. The outer whorl is ornamented by blunt umbilical bullae. These give rise to delicate ribs which, together with intercalaries, strengthen on the outer flank into broad, blunt ribs that terminate in blunt, bullate ventrolateral clavi. Low, broad ribs link these to weak siphonal clavi borne on a low, siphonal ridge.

AMNH 44334 is a large, completely septate fragment with a whorl height of 53.9 mm (fig. 11). Coiling appears to have been moderately evolute with an umbilicus of moderate depth. The costal whorl section is depressed and trapezoidal with a whorl width-to-height ratio of 1.22:1, the greatest width lying just outside the umbilical shoulder (fig. 12). The flanks are very broadly rounded and convergent, the ventrolateral shoulders are more narrowly rounded, and the venter is very broad and somewhat flattened. The fragment extends for approximately one-third of a whorl. There are three large, blunt umbilical bullae that extend across the inner flanks; each bulla gives rise to a pair of long, broad ribs, with one or two long or short ribs interca-

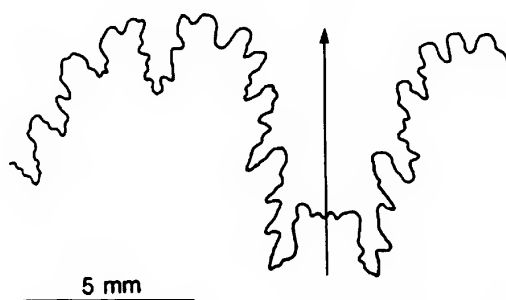


Fig. 13. *Calyoceras* (*Calyoceras*) sp., AMNH 44333, AMNH locality 3155 (same specimen as in fig. 10A-C). Part of the next-to-last visible suture at D = 26.4 mm, H = 9.7 mm.

lating. All ribs bear low, blunt, weakly clavate ventrolateral nodes, linked by low, broad swellings to very weak siphonal nodes.

The suture is moderately incised, with a broad, asymmetrically bifid E/L (fig. 13).

DISCUSSION: Feeble ornament serves to distinguish these fragments from others in the collection. They may be weakly ornamented variants of *C. (C.) boreale* n. sp., but our sample size is too small to demonstrate continuous variation between the two forms.

OCCURRENCE: *Metoicoceras mosbyense* zone of the Greenhorn Formation on the west side of the Belle Fourche Reservoir in the S½ sec. 15, T9N, R3E, Butte County, South Dakota.

SUBGENUS *CALYOCERAS* (*GENTONICERAS*) THOMEL, 1972

TYPE SPECIES: *Ammonites gentoni* Brongniart, 1822: 83, 392, pl. 6, fig. 6, by original designation (Thomel, 1972: 65).

Calyoceras (*Gentoniceras*) sp. Figure 10D, E

DESCRIPTION: AMNH 44318 is a crushed specimen 52.2 mm in diameter, consisting of a portion of the inner whorls and part of the body chamber, which extends for nearly two-thirds of a whorl. Coiling is moderately evolute, the umbilicus comprising approximately 30 percent of the diameter. The umbilical wall is low with a narrowly rounded shoulder. The inner whorls show massive umbilical bullae, eight or nine per whorl. A

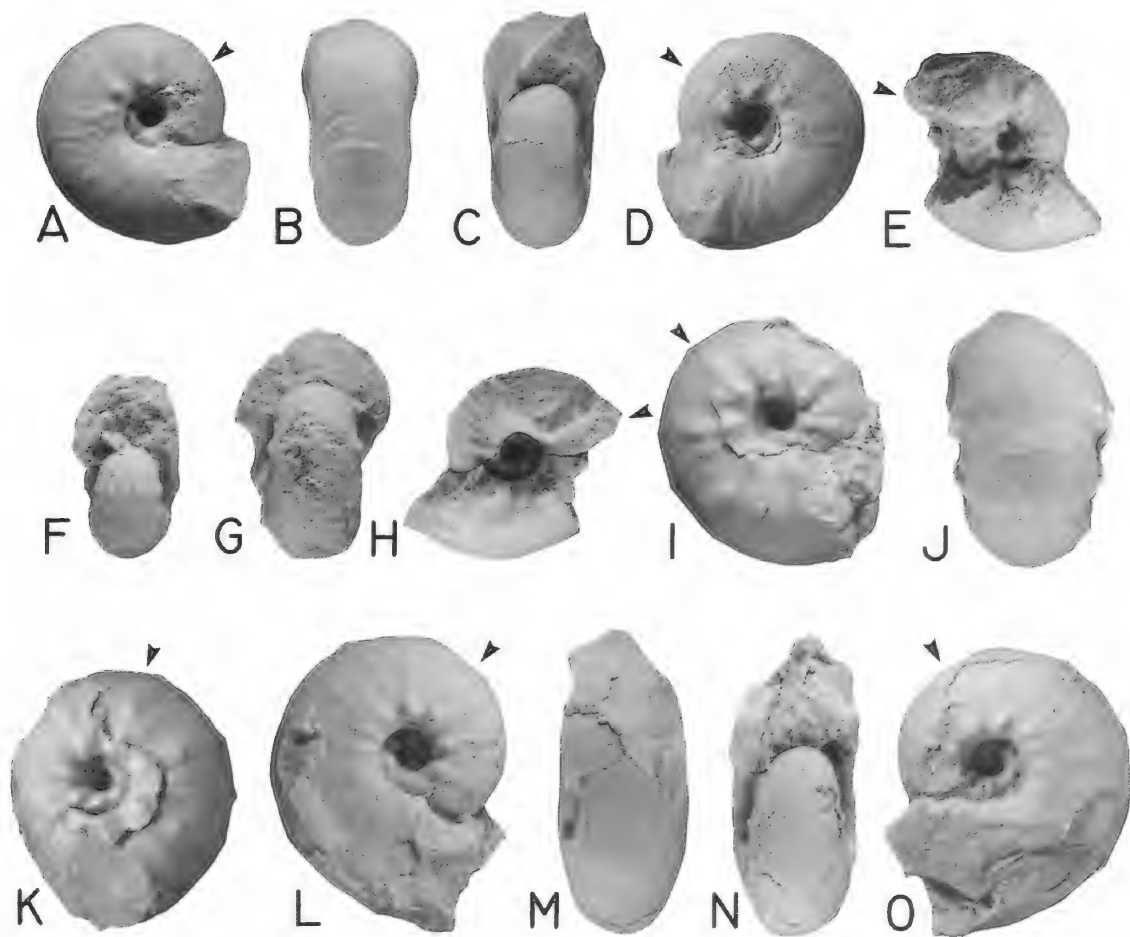


Fig. 14. *Protacanthoceras proteus vascoceratoides* Wright and Kennedy, 1987, AMNH locality 3155. A–D. AMNH 44320, $\times 1.5$. A, Right lateral; B, ventral; C, apertural; D, left lateral. E–H. AMNH 45287, $\times 1.5$. E, Right lateral; F, apertural view of early whorls after removal of part of the body chamber; G, apertural; H, left lateral. I–K. AMNH 44319, $\times 2.0$ (same specimen as in fig. 15). I, Right lateral; J, ventral; K, left lateral. L–O. AMNH 44321, $\times 1.5$. L, Right lateral; M, ventral; N, apertural; O, left lateral.

single ventrolateral tubercle is also preserved. The body chamber portion has seven primary ribs. They arise at low, elongate umbilical bullae and are straight and prorsiradial on the inner to middle flanks, strengthening and projecting slightly forward and concave on the outermost flanks and ventrolateral shoulder, and passing straight across the venter. One or two intercalated ribs arise low on the flanks; these ribs strengthen to match the primary ribs on the ventrolateral shoulder and venter.

OCCURRENCE: *Metoicoceras mosbyense* zone of the Greenhorn Formation on the west

side of the Belle Fourche Reservoir in the S $\frac{1}{2}$ sec. 15, T9N, R3E, Butte County, South Dakota.

GENUS *PROTACANTHOCERAS* SPATH, 1923

TYPE SPECIES: *Ammonites bunburianus* Sharpe, 1853: 25, pl. 9, fig. 3; by original designation (Spath, 1923: 144).

Protacanthoceras proteus vascoceratoides
Wright and Kennedy, 1987
Figures 14, 15

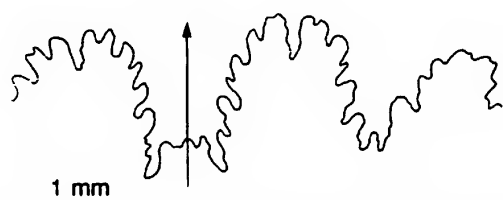


Fig. 15. *Protacanthoceras proteus vascoceratoides* Wright and Kennedy, 1987, AMNH 44319, AMNH locality 3155 (same specimen as in fig. 14I–K). Part of the last suture at D = 11.4 mm, H = 5.8 mm.

Protacanthoceras proteus vascoceratoides Wright and Kennedy, 1987: 217, pl. 55, fig. 4.

TYPE: Holotype, by monotypy, is BMNH C84922 from the phosphatic upper Cenomanian *Calycoceras guerangeri* zone fauna of bed C of the Cenomanian Limestone at the White Hart Sandpit, Wilmington, Devon, U.K.

MATERIAL: Seven specimens, AMNH 44319–44324 and 45287, of which two are juveniles with portions of the body chamber preserved (AMNH 44319, 44324), two are small phragmocones (AMNH 44322, 44323), and three are adults (AMNH 44320, 44321, and 45287). Of the adults, AMNH 44320 is a microconch, and AMNH 44321 is a macroconch.

DESCRIPTION: Dimensions of four of the specimens are listed in table 2. Coiling is involute in all specimens; a tiny, deep umbilicus comprises 22–25 percent of the diameter. The umbilical wall is flattened, and the umbilical shoulder is narrowly rounded. The costal whorl section is depressed and reniform with a whorl width to height ratio of up

to 1.45:1. Low, distant primary ribs, eight per whorl, arise at the umbilical seam and are weak on the umbilical wall, strengthening into strong bullae on the umbilical shoulder. These bullae are linked by strong, barlike ribs to subequal, conical, inner ventrolateral tubercles. One or two weak to strong ribs intercalate between the bullate primaries; lacking umbilical bullae, they may or may not develop weak, inner ventrolateral tubercles. Ribs are very weak and prorsiradiate on the ventrolateral shoulder and are projected forward on the venter, where they are accompanied by striae. Weak, outer ventrolateral and siphonal clavi correspond to the stronger bullate ribs; a few correspond to those non-bullate, intercalated ribs that bear inner ventrolateral tubercles; as a result, there are more siphonal clavi than there are umbilical bullae. All tubercles decline and disappear on the last part of the adult phragmocone leaving an ornament consisting of numerous, delicate umbilical bullae. Each bulla gives rise to one or two low, delicate ribs; these, together with long and short intercalated ribs, are flexuous and prorsiradiate on the inner to middle flanks; they decline on the outermost flanks, which are covered instead by delicate riblets and lirae; these cross the venter with a broad convexity. Bullae disappear toward the adoral end of the adult body chamber. Ribbing strengthens near the adult aperture and is closely spaced, flexuous, distant, and wiry, and projected into a broad linguoid peak over the venter (fig. 14B).

The suture has little-incised elements; E/L is relatively broad and bifid and L is small and asymmetrically bifid (fig. 15).

DISCUSSION: AMNH 44319 (fig. 14I–K) is

TABLE 2
Dimensions of *Protacanthoceras proteus vascoceratoides* (in millimeters)^a

Specimen	Description	Antidi-morph ^b	D	W ^c	H ^c	W:H ^c	U	BC/∠ (°)
AMNH 44319	Juvenile	—	15.9 (100)	10.9 (68.6)	7.5 (47.2)	1.45:1	4.0 (25.2)	171
AMNH 44320	Adult	m	19.6 (100)	10.0 (51.0)	8.9 (45.4)	1.12:1	4.4 (22.4)	260
AMNH 44321	Adult	M	26.8 (100)	11.2 ^d (41.8 ^d)	11.2 ^d (41.8 ^d)	1.00:1 ^d	6.1 (22.8)	268
AMNH 44324	Juvenile	—	13.8 (100)	8.2 (59.4)	6.5 (47.1)	1.26:1	3.0 (21.7)	179

^a Figures in parentheses are dimensions as a percentage of diameter.

^b M = macroconch; m = microconch; — = unknown.

^c Measured in costal section if ribs are present.

^d Estimate because the specimen is slightly crushed.

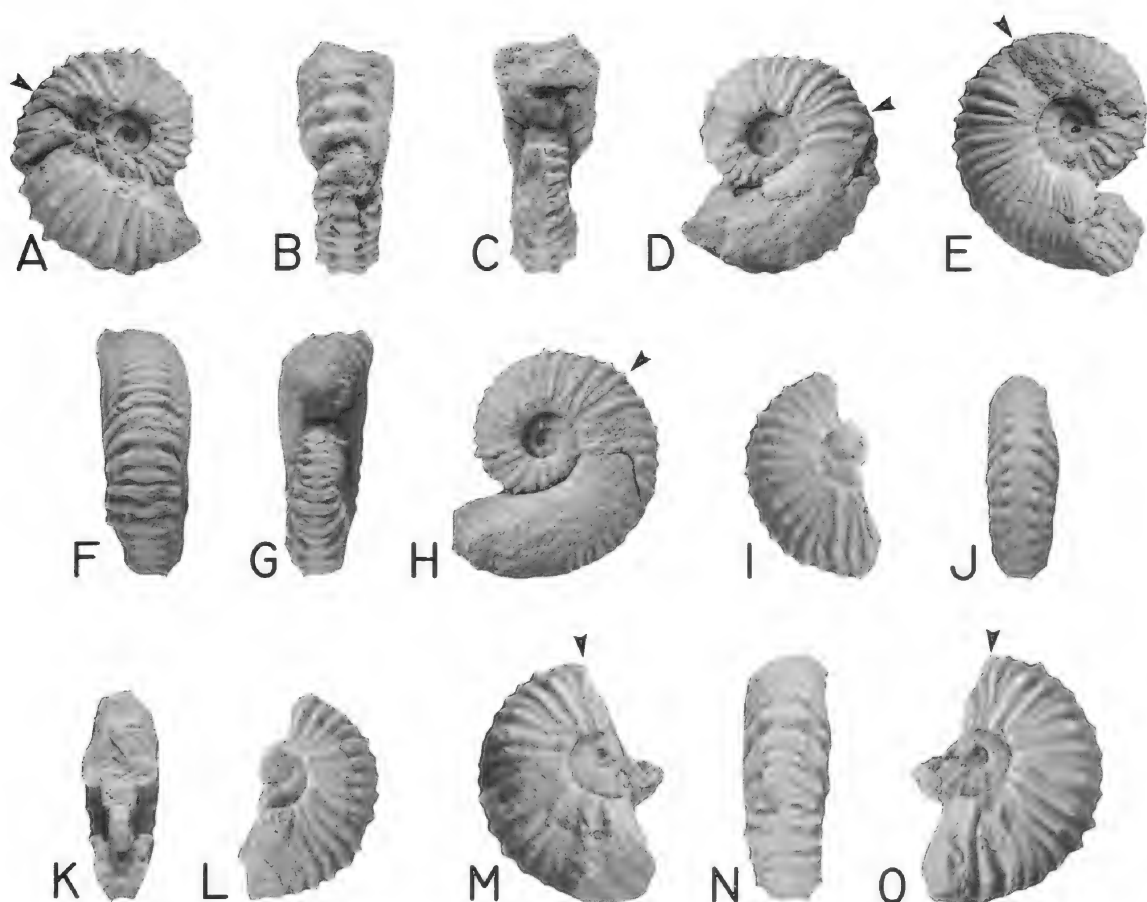


Fig. 16. *Neocardioceras transiens* n. sp., AMNH locality 3155. A–D. Paratype AMNH 45284. A, Right lateral; B, ventral; C, apertural; D, left lateral. E–H. Paratype AMNH 45285 (same specimen as in fig. 17). E, Right lateral; F, ventral; G, apertural; H, left lateral. I–L. Paratype AMNH 45286, $\times 1.5$. I, Right lateral; J, ventral; K, apertural; L, left lateral. M–O. Holotype AMNH 44325, $\times 1.5$. M, Right lateral; N, ventral; O, left lateral.

identical to the holotype of *P. proteus vascoeratooides* (Wright and Kennedy, 1987: 217, pl. 55, fig. 4). The very weak ventral ornament and loss of all but umbilical bullae on the adult body chamber immediately distinguish this subspecies from *P. proteus proteus* Wright and Kennedy, 1980 (p. 98, figs. 49, 50, 57; Wright and Kennedy, 1987: 216, pl. 55, figs. 9, 17, 18, 23; text-figs. 82B, 83G, H) and *P. proteus baylissi* Wright and Kennedy, 1980 (p. 96, figs. 51, 58; Wright and Kennedy, 1987: 216, pl. 55, figs. 21, 22; text-fig. 84P), both of which have coarse ribbing on the adult body chamber.

OCCURRENCE: The holotype is from the upper Cenomanian *Calycoceras guerangeri* zone

of Devon, U.K. The material described here comes from the *Metoicoceras mosbyense* zone of the Greenhorn Formation on the west side of the Belle Fourche Reservoir in the S $\frac{1}{2}$ sec. 15, T9N, R3E, Butte County, South Dakota.

GENUS *NEOCARDIOCERAS* SPATH, 1926

TYPE SPECIES: *Ammonites juddii* Barrois and de Guerne, 1878: 46, pl. 1, figs. 1, 2, by original designation (Spath, 1926b: 81).

Neocardioceras transiens, new species Figures 16, 17

Neocardioceras sp. Cobban, 1988: 24, pl. 10, figs. 71, 72.

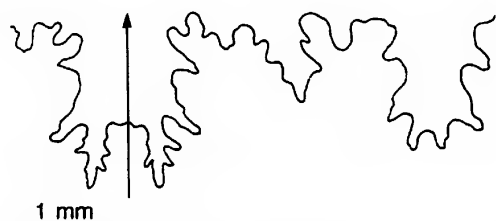


Fig. 17. *Neocardioceras transiens* n. sp., para-type AMNH 45285, AMNH locality 3155 (same specimen as in fig. 16E–H). Part of the last suture at H = 8.5 mm.

DERIVATION OF NAME: Latin, *transiens*, across, beyond.

DIAGNOSIS: A species of *Neocardioceras* with umbilical bullae, inner ventrolateral tubercles, and outer ventrolateral clavi; weak, siphonal clavi may be present on inner whorls but disappear on the adult body chamber, where strong transverse ribs link outer ventrolateral clavi.

TYPES: Holotype AMNH 44325 (fig. 16M–O), paratypes AMNH 44326–44328, 45284–45286, 45288, and 45289, all from AMNH locality 3155.

DESCRIPTION: The dimensions of the holotype and three of the paratypes are listed in table 3. The holotype is an adult with part of the inner whorls and most of the body chamber preserved (fig. 16M–O). Coiling is evolute, with the umbilicus comprising 27 percent of the diameter. The umbilical wall is flattened and subvertical with a narrowly rounded umbilical shoulder. The whorl section is compressed, oval in intercostal section, and polygonal in costal section; the greatest width is at the umbilical bullae. There are eight or nine sharp umbilical bullae on

the last half-whorl of the body chamber. They project into the umbilicus and give rise to strong, straight, prorsiradiate ribs, which bear pointed, inner ventrolateral tubercles; these are connected by strong, slightly prorsiradiate ribs to prominent, outer ventrolateral clavi. There are up to three ribs between bullate primaries; some of these ribs are long, non-bullate primaries, but others arise both high and low on the flanks, and bear inner ventrolateral tubercles and outer ventrolateral clavi, only outer ventrolateral clavi, or neither one nor the other. Low, broad ribs connect the outer ventrolateral clavi across the venter at the beginning of the body chamber, and bear delicate, siphonal clavi. This pattern of ornament progressively changes in an adoral direction on the body chamber so that outer ventrolateral clavi are instead linked across the venter by strong transverse ribs. Ribs crowd and tubercles decline markedly on the final sector of the shell just adapical of the adult aperture (fig. 16E). Smaller paratypes have weak or no siphonal clavi.

The suture is little incised and has a broad, asymmetrically bifid E/L and narrower, symmetrically bifid L (fig. 17).

DISCUSSION: *Neocardioceras transiens* n. sp. differs from all other described species of this genus in the variable development of siphonal clavi on the inner whorls and their loss on the adult body chamber, where strong transverse ribs link outer ventrolateral clavi. This species is thus transitional in morphology between species of *Neocardioceras* and *Watinoceras* Warren, 1930.

OCCURRENCE: *Metoicoceras mosbyense* zone of the Greenhorn Formation on the west side of the Belle Fourche Reservoir in the S½ sec. 15, T9N, R3E, Butte County, South Da-

TABLE 3
Dimensions of *Neocardioceras transiens*, new species (in millimeters)^a

Specimen	Description	D	W ^b	H ^b	W:H ^b	U	BC/L ^c
Holotype AMNH 44325	Adult	22.5 (100)	8.0 (35.6)	9.7 (43.1)	0.82:1	6.1 (27.1)	197
Paratype AMNH 45284	Adult	30.4 (100)	12.8 ^c (42.1 ^c)	12.7 (41.8)	1.01:1 ^c	9.3 (30.6)	124
Paratype AMNH 45285	Adult	33.0 (100)	12.5 (37.9)	14.0 (42.4)	0.89:1	10.0 (30.3)	156
Paratype AMNH 45288	Phragmocone	15.7 (100)	6.8 ^c (43.3) ^c	8.6 (54.8)	0.79:1 ^c	5.6 (35.7)	—

^a Figures in parentheses are dimensions as a percentage of diameter.

^b Measured in costal section if ribs are present.

^c Estimate because the specimen is not well preserved.

kota. A phragmocone from the Frontier Formation of north-central Wyoming figured by Cobban (1988: 24, pl. 10, figs. 71, 72) probably can be assigned to this species.

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